OST ANALYSIS SHEET

SUBJECT: OST review on Kevin Trenberth's recommendations to Jack Kelly in a letter dated 1/7/02 regarding: 1) Increasing radiosonde mandatory-level reporting from 17 to 30 levels, and make the same change in reanalysis products, 2) changing from sigma to a hybrid vertical coordinate in NCEP NWP models, and 3) the need for a systems approach to climate observations

ACTION REQUIRED: OST is to supply recommendations to Bob Livezey COB 2/7/03 who is coordinating NWS response.

SUMMARY:

1) Trenberth believes current NCEP/NCAR reanalysis at standard pressure levels causes loss of information and accuracy in derived diagnostics. His recommendation is to increase the number of standard pressure levels in the reanalysis from 17 to 30 with a vertical resolution of 25 mb below 700 mb and 50 mb from 700 mb to 100 mb. These new levels should also become standard levels for reporting radiosonde data.

2) Trenberth points out problems found in the stratosphere of NCEP analyses are pathological, because they are a result of using the sigma coordinate system in their NWP models. His recommendation is to change to a hybrid coordinate (sigma at low levels, transition to pressure above 100 mb).

3) Trenberth recommends a systems approach for the operational climate observation to ensure that the data and information necessary to adequately monitor climate will be delivered. This approach includes:

   - Development of improved networks to adequately sample critical climate state and forcing variables.
   - Implementation of the 10 climate monitoring principles outlined by NRC and development of the required management guidelines.
   - Analyzing observations into products.
   - Creating an oversight facility to monitor and rectify problems in the system itself.
   - Increasing focus on the climate needs related to management, access, and archival of the data

ANALYSIS:

1) Increasing Number of Mandatory Levels

The NWS radiosonde replacement system (RRS) will have software to provide one-second resolution upper air data in BUFR form. One-second resolution data will enable vertical resolution of one set of data points every five meters. NCEP is currently outputting 21 of the 26 tropospheric pressure levels requested. They are

willing to consider additional levels in the event of another global reanalysis

- ❑ Software development cost to increase to one-second data is about $20K (estimated by Thomas Roberts). Cost to perform another reanalysis was estimated in an EMC proposal, which Robert Livezey holds.
- ❑ Other Issues: None

2) Going to a hybrid vertical coordinate

- ❑ Advantages and drawbacks of pressure coordinate
  - o Simpler form of governing equations (vertical p velocity, pressure gradient force)
  - o Intersect the ground of variable topography with pressure surfaces, causing the lower boundary condition difficult to handle
- ❑ Advantages and drawbacks of sigma coordinate
  - o Easier to apply the lower boundary condition
  - o Difficult to compute the pressure gradient force, which becomes the difference of two terms of large magnitude
  - o The problem becomes especially serious in the stratosphere over steep mountains
- ❑ Advantages and drawbacks of isentropic coordinate
  - o The coordinate surfaces are material levels in an atmosphere characterized by adiabatic motion. Hence, there is no vertical motion in such a coordinate frame. Since the real atmospheric motion in the upper troposphere and stratosphere is quasi-adiabatic, the isentropic system has special advantages. By properly applying isentropic coordinate, it would greatly minimize vertical truncation errors.
  - o A potential difficulty is that it may fold in time near the ground.
- ❑ Using hybrid coordinate
  - o Tropospheric sigma and stratosphere pressure coordinate
  - o More advanced sigma-isentropic coordinate
- ❑ NCEP is aware of problems associated with the use of a sigma coordinate system which manifest themselves primarily in the stratosphere. NCEP/EMC has developed a sigma-pressure hybrid model, similar to that used at ECMWF, and is testing a 64 level configuration as well as the ECMWF 60 level configuration. EMC anticipates that this model will become operational in the latter part of 2003 if current testing demonstrates advantages
- ❑ Cost: The change of coordinate system is in the EMC test and development plan and will use the base funding.

3) Systems Approach to Climate

- ❑ Good idea in principle, however, there will be issues related to continuity studies and oversight.
- ❑ Cost: Unknown
- ❑ Other Issues: None at this time

OPTIONS:

1) More levels: Using RRS one-second resolution upper air data in BUFR form should solve this problem. This high resolution data will more than meet the needs of Trenberth request for additional standard levels. From the high resolution data, set pressure levels could be generated by data users with great definition.

   More output levels from reanalysis: Costlier issue. Would need to perform new reanalysis. NCEP is developing plans for this.

2) Hybrid Coordinates: Using hybrid coordinate with sigma in the lower troposphere and transition to isentropic in the stratosphere

   Continue NCEP approach: According to Stephen Lord, *EMC has derived the sigma-isentropic hybrid model from the current NCEP Global Model.* The development has taken about a year of work and testing is now beginning for a possible implementation in the autumn.

3) Systematic Approach: Pursue objectives subject to policy and costs.

RECOMMENDATION:

1) Build 2 of the radiosonde replacement system scheduled for April 2004 will provide one-second resolution data in BUFR form allowing users to define pressure levels.

   Examine requirements and costs to perform new reanalysis. In any new reanalysis, increase the number of standard pressure levels from 17 to 30.

2) Continue testing and implement sigma-pressure hybrid coordinate in the NCEP global forecast system.

   Continue to develop and test sigma-isentropic hybrid system in EMC and compare the result with that from the sigma-pressure system.

   Make modifications for the subgrid-scale orographically induced gravity wave drag parameterization scheme and upper boundary condition after changing the model coordinate system.

3) Support systematic approaches to solve observing problems where appropriate, *e.g.*, RRS data continuity study, global and regional climate data reanalysis, COOP modernization program, Climate Reference Network, ASOS upgrade, *etc.*

VIEWS OF OTHERS:

- ❑ NCEP (Louis Uccellini)

  NCEP official response

  1) Sigma coordinate system

     NCEP is aware of problems associated with the use of a sigma coordinate system which manifest themselves primarily in the stratosphere. NCEP/EMC has developed a sigma-pressure hybrid model, similar to that used at ECMWF, and is testing a 64 level configuration as well as the ECMWF 60 level configuration. EMC anticipates that this model will become operational in the latter part of 2003 if current testing demonstrates advantages.

  2) Output pressure levels

     NCEP's operational Global Forecast System (GFS) products have been upgraded many times since the 1995 system which was used as the prototype for the NCEP-NCAR Reanalysis. The current tropospheric GFS output pressure levels are: 1000, 975, 950, 925, 900, 850, 800, ...100 mb. Thus, NCEP is putting out 21 of the 26 levels you are recommending. In the event of another global reanalysis, we will consider your suggestion to add 1025, 875, 825, 775 and 725 mb. NCEP's Regional Reanalysis outputs on the following pressure levels: 100, 975, 950, 925, 900, 850, 800,...300, 275, 250, 225, 200, 175, 150 and 100 mb. Stratospheric output pressure levels continue to be at WMO mandatory levels but that, too, should be examined for the next global reanalysis.

  3) Observing System Recommendations

     NCEP agrees with these recommendations and supports a systems approach to the observing problem. Observations for climate and weather should be part of an integrated, robustly funded, program which focuses on requirements first and hardware second. Weaknesses in the current observing system include data access, archiving and quality control. These weaknesses can be ameliorated to a great extent by continuous support for a global and regional (North American) Reanalysis capability. It is also important, however, to recognize that addition of new components to the observing system have the potential to produce apparent climate change simply because a better observed atmosphere (or ocean, land surface or sea ice) may have different climatic mean and variance.

- ❑ OS7 (Carl Bower)

  Comments on increasing radiosonde reporting standard levels

  The revision of the WMO TEMP messages to accommodate this change will

probably never happen. The old fixed code forms we are accustomed to will be replaced by what is known as table driven codes. The advantages of the table driven codes are self-definition, flexibility, and expandability. *The WMO Commission for Basic Services has recommended that changes to the fixed code forms be frozen* since minor changes to existing codes could mean major software changes and substantial costs for most WMO Member States.

The table driven codes, BUFR (Binary Universal Form for the Representation of meteorological data) have significant advantages over the traditional alphanumeric codes. They are universal and flexible, and can be easily expanded to satisfy all observational requirements including national needs for specific data exchange. There is a transition plan to the table driven forms. Specifically, by Nov 2005, operational exchange will be initiated. This does not mean that exchange can't start earlier. Initially, data will be provided in both the fixed code forms and the BUFR form. The migration to the BUFR form is scheduled to be complete by Nov 2010 for upper air data.

The NWS with *the radiosonde replacement system (RRS) will have software to provide one-second resolution upper air data in BUFR form*. Our first build will have high resolution capability for archival of data at the NCDC. Build 2 which should be available in the second half of 2004 will have capability for high resolution data provision to NCEP for model use. These high resolution data will only be available for the radiosonde replacement system sites. It will be 2006 to 2007 before our entire upper air network will have the high resolution data capability in the new BUFR form. One-second resolution data will enable vertical resolution of one set of data points every five meters. Each one-second set of pressure, temperature, relative humidity, and wind data points will have a corresponding latitude, longitude, height, and time associated with the data. The latitude, longitude, and height position information can be transformed into any analysis model coordinate system.

- ❑ OST (Thomas Roberts)

  <u>Estimation of the cost for increasing radiosonde reporting levels</u>

  The new system generates one second data that will allow the increased reporting levels. Software modifications in the workstation would have to be done. The costs for this would not be significant, maybe a man-month or two (~ $20K) to develop and test. However, we already have a plan to add the capability in Build 2 to generate and transmit high-resolution (one second) data products. So, *going from 17 to 30 reporting levels is essentially a mute point.*

- ❑ Donald R. Johnson (NOAA Special Project Scientist)

  <u>Comments on using isobaric coordinate in the upper levels</u>

  There are some issues concerning diagnostics and modeling of the stratosphere which Trenberth has overlooked. The major point being that in one of his studies,

one really cannot partition the total energy into its various components, internal, geopotential and kinetic, treat them individually and that sum to close the total energy budget accurately. Consider the determination of the dry static energy (Montgomery Stream Function). Danielsen showed that one must integrate the Exner function to be able to determining a distribution of the Montgomery Stream Function, such that one can accurately specify the geostrophic wind on isentropic surfaces. In other words, the discrete numerics of determining the geopotential energy at high levels from vertical integration of temperature and its first derivative lead to noisy fields at high levels and incompatibilities of the structure between internal and geopotential energies. This same problem emerges in attempting to interpolate components of energy from any one coordinate system to another coordinate system in the higher levels as you most likely know. As such, the current NCEP global model is dealing with the structure accurately within the sigma frame work of its computations. Going to isobaric surfaces in the upper levels in the hybrid structure being utilized will make for accurate analysis of the structure for reanalysis efforts as observed and understood from an isobaric perspective, and thus outwardly assist in the accuracies of Trenberth's partitioning of the various components of energy. However, *it will not resolve in a basic sense the inherent computational difficulties and errors of a proper determination of the balance of dry static energy as the sum of the balances of geopotential and internal energies or should I say enthalpy*. Note I have not raised the more general issue of the transfer of total flow energy by pressure work.

- ECMWF, NCAR and UW

  ECMWF and NCAR models have already adopted sigma-pressure hybrid coordinate. The sigma-isentropic hybrid coordinate model has been developed in the University of Wisconsin and some other institutes.